U.S. Research Vessel Surface Meteorology Data Assembly Center

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Project Summary

The central activity of the U.S. Research Vessel Surface Meteorology Data Assembly Center (DAC) is the continued development of the Shipboard Automated Meteorological and Oceanographic System (SAMOS) initiative (http://samos.coaps.fsu.edu/). The SAMOS initiative focuses on improving the quality of and access to surface marine meteorological and oceanographic data collected *in-situ* by automated instrumentation on research vessels and ships of opportunity. The DAC activities focus primarily on NOAA Strategic Plan Goals 2 and 3 by providing high quality weather and near surface ocean data for use in validating satellite products, global air-sea flux analyses, and model fields. Research vessels are mobile observing platforms that are an essential component of the global ocean observing system. These vessels travel to remote and hard to observe ocean locations that are far from normal shipping lanes.

The rationale for this activity centers on the desire to understand the physical and thermodynamic interaction between the ocean and atmosphere. This interaction is key to our understanding of how marine weather systems evolve, how they impact the ocean, and how the oceans impact the weather. On longer time scales, understanding the interaction between the ocean and atmosphere is necessary to assess our changing global climate system. The role of the DAC is providing the high quality marine meteorological and surface ocean measurements to the research and operational community so that they can address these ocean-atmospheric interactions. High quality observations are essential to our scientific understanding of the ocean-atmosphere interactions.

The DAC was established at the Florida State University specifically to coordinate the collection, quality evaluation, distribution, and future archival of SAMOS data. SAMOS are typically a computerized data logging system that continuously records navigation (ship's position, course, speed, and heading), meteorological (winds, air temperature, pressure, moisture, rainfall, and radiation), and near ocean surface (sea temperature and salinity) parameters while a vessel is at sea. Measurements are recorded at high-temporal sampling rates (typically 1 minute or less). The DAC collaborated with the Woods Hole Oceanographic Institution (WHOI) to design a ship-to-shore-to-user data pathway for U.S. research vessel SAMOS data. In the past, the data flowed from ship to shore only in a delayed-mode with a 3 month to 2 year lag between collection and availability to the user community. The new data pathway supports automated data transmission from each ship to the DAC on a daily basis. A "preliminary" version of the SAMOS data are available on-line within 5 minutes of receipt by the DAC. The preliminary data undergo common formatting, metadata enhancement, and automated quality control. Visual inspection and further scientific quality control result in a "research" quality SAMOS product which are distributed with a delay of several weeks. All quality-evaluated research vessel data at the DAC are freely available to the user community (http://www.coaps.fsu.edu/RVSMDC/html/data.shtml), and we continue to work with several world data center archives (e.g., National Oceanographic Data Center, National Center for Atmospheric Research) to ensure long term stewardship of these data.

Accomplishments

Over the past year our efforts have focused on the continued development of the SAMOS Initiative. We wrapped up a successful data exchange pilot project with WHOI and now are receiving routine data transmissions from the *Knorr* and *Atlantis* while they are at sea. We continued to expand our SAMOS data quality evaluation system and have improved access to both preliminary data files and metadata on our web pages. Throughout the year DAC personnel have been actively promoting the SAMOS Initiative through meetings and working groups, and in May 2006 the DAC coordinated the 1st Joint SAMOS/GOSUD Workshop in Boulder, Colorado (with supplemental funding from a one-off add task from NOAA/OCO). Finally, we continued our delayed mode data processing for NOAA vessels and have actively recruited additional vessels to participate in SAMOS.

Deliverables for FY 2006 included:

1. Recruiting additional vessels to provide daily data transfers to the SAMOS DAC through collaboration with UNOLS, USCG, NOAA, etc.
2. Establishing, where possible, data transfers from international vessels through collaboration with GOSUD and international research vessel operators.
3. Continuing daily and delayed mode quality processing and distribution of meteorological data from select NOAA vessels and vessels recruited to SAMOS
4. Evaluating and improving data ingest and quality control system based on FY 2005 experience.
5. Expanding data and metadata distribution, including collaboration with national archive centers.
6. Compare R/V observations to global reanalysis products and to independent marine platforms (e.g., tropical moorings).
7. Produce a one or more written reports from the 1st Joint GOSUD/SAMOS Workshop (from one-off FY 2006 add task).

The following accomplishments address the deliverables. Also noted are impediments to achieving the deliverables.

Vessel recruitment [Deliverable 1]

Recruitment of additional vessels to participate in the SAMOS Initiative has been an ongoing, albeit slow, process. The project manager (Smith) attended the annual UNOLS RVTEC meeting in Oregon in November 2005 and had good conversations with several vessel operators. Most expressed interest in participating, but initiating new data transfers is still difficult in these times of tight operational budgets for research vessels. In spring 2006 a plan was established with NOAA OMAO to use a new fisheries vessel, the *Bigelow*, as a pilot vessel to establish SAMOS data transfers from NOAA vessels. Most NOAA vessels are equipped with the scientific computing system (SCS) software and the latest version of SCS will be installed on the *Bigelow*. The new SCS will facilitate SAMOS data transfers and once tested can then be spread to other vessels in the NOAA fleet. Due to problems with the *Bigelow* at the shipyard, early tests of data transmissions from NOAA vessels were conducted in August 2006 with data from the *Miller Freeman*. In addition to the NOAA vessels, a dialog is underway with several other UNOLS operators to bring additional vessels into the SAMOS Initiative.

Daily processing of Knorr and Atlantis data [Deliverable 3]

The DAC completed development of the preliminary processing of SAMOS observations received via daily email messages from participating research vessels. Currently two vessels, the *Knorr* and *Atlantis*, have automated their transmission of daily data messages (which include all one minute average observations for the day) to the DAC. The data messages are generated on each vessel by scripts developed by WHOI. Once the data file arrives at the DAC (as an attachment to an email), the data are unpacked, verified that they conform to the format and parameters expected for the individual vessel, and finally are converted to a common netCDF format. The data for each day are then passed through an automated quality evaluation program and data quality statistics are calculated prior to the file being posted for users on the web and ftp (see below). The entire process from arrival at the DAC to distribution of the preliminary data files is fully automated. Preliminary files appear on the data distribution site within 5 minutes of their arrival at the DAC (typically shortly after 0000 UTC). Strict version control is used to track individual data files received from their original email attachment to the preliminary netCDF files posted for users.

The expanded spatial coverage of data received, processed, and on-line from the *Knorr* and *Atlantis* is shown in Figure 1 for FY 2005 and 2006. In FY 2005, the Knorr and Atlantis provided approximately 300,000 individual one minute marine reports. Their contributions doubled to ~600,000 reports in FY 2006, in part due to the inception of SAMOS data transfers in the middle of FY 2005. The quality of the preliminary data for both vessels was good with on average less than 5% of the individual data values being flagged as suspect. The majority of the suspect observations were shortwave radiation values below zero. These unrealistic values often occur because the shortwave sensor is not sensitive to low values and can report negative values at night. Several minor problems with the underway sensors (e.g., an RH sensor that had drifted and was recording anomalously high values) were noted by the DAC analyst and were reported to WHOI. These near-real time reports resulted in rapid repair of problems and a continuous stream of high quality observations.

Continue delayed-mode evaluation of NOAA ship data [Deliverable 3]

The DAC continues to evaluate the quality of the meteorological observations collected by the NOAA vessels *Ronald Brown* and *Ka'Imimoana*. Over the past year the DAC has received and processed *Ronald Brown* observations for the periods May 2004 – March 2005 (Rolph and Smith 2005) and July 2005 – November 2005 (Rolph and Smith 2006). We continue to see improvements in the quality of the meteorological observations from the *Ronald Brown* and these data make up an extensive (1999-2005) data set for a wide array of satellite and model validation studies. In September 2006 we received the underway data from the Ronald Brown covering the period 17 February – 11 September 2006. The data for the *Ka'Imimoana* tend to arrive in multiple data formats which complicates their conversion for quality processing. We recently converted observations for September 2004 - December 2005 and have completed the visual quality evaluation. The quality report and data files for this period of Ka'Imimoana data will be posted on-line shortly. We continue to receive and process additional data for the *Ka'Imimoana* on a regular basis.

Delayed-mode SAMOS processing [Deliverable 4]

The initial processing of SAMOS observations is completed in near-real time (see 1 above). Due to data logging problems on the ship or communication drop-outs, some data arrive several days

after they were collected. Often the data are noted to be missing by the analyst at the DAC and arrive after the analyst notifies the vessel technician at sea. In addition, data for a single day can be fragmented and may arrive as multiple files attached to an email. As a result, the DAC developed a method to merge multiple files for a single observing day into a combined, delayed-mode data file. This merged file undergoes additional automated and visual data quality evaluation and is then released as a "research-quality" SAMOS data file for the particular observation day.

Over the past six months, the code to merge multiple files has been developed, tested, and is now operational. The merge program is designed to eliminate duplicate records from the files being merged. Duplicates are eliminated based on a series of rules that take into account the automated quality control applied to the preliminary data files. The merge process is fully automated and the merged files are tracked within the file tracking data base. Currently the merge occurs 10 calendar days after the observation day (when the preliminary data should arrive at the DAC). Using the file tracking database, the analyst can easily reference the original file pieces that were merged to create a single data file for each observation day. Once merged, a summary of the data quality flags on the new file is produced and stored in the database. Developing the delayed-mode processing has been slowed by the heavy demands on our computer programmers (from multiple projects) but we anticipate completion of the codes for visual data quality inspection of the merged files late in 2006.

Public access to observations and metadata [Deliverables 1, 3, 5 and 7]

A web presence for SAMOS has been completed and is accessible at: http://samos.coaps.fsu.edu/. The pages provide information on the SAMOS Initiative as a whole, provides links to relevant literature, and access to past SAMOS workshops (including the 1st Joint GOSUD/SAMOS Workshop). Through these pages, the DAC provides access to the preliminary quality controlled data for the *Knorr* and *Atlantis*. A metadata portal allows users to access ship- and parameter-specific metadata along with digital photos and schematics of participating vessels. Both the metadata portal and data access are user searchable. Criteria include searches by vessel and the observation dates. The web site also provides access to desired SAMOS parameters, accuracy requirements, and training materials. In September 2006 an extensive ship recruiting section was added to the SAMOS web page that includes necessary metadata forms and data specifications for vessels interested in contributing to the SAMOS Initiative.

Liaison activities [Deliverables 2 and 7]

The SAMOS DAC serves as the international coordination office for the SAMOS Initiative. In this capacity, DAC personnel facilitate U.S. and international collaborations on topics ranging from data accuracy, data acquisition and exchange, training activities, and data archival. As a result, Smith and Bourassa have presented at numerous conferences and workshops (see below).

Foremost among the liaison activities was the coordination of the 1st Joint 1st Joint Global Ocean Surface Underway Data (GOSUD)/Shipboard Automated Meteorological and Oceanographic System (SAMOS) Workshop held in Boulder, CO on 2-4 May 2006. In response to an FY 2006 Add Task, NOAA supported the travel, logistics, and venue for the workshop through the UCAR Joint Office for Science Support (JOSS). The SAMOS DAC supported all planning of the scientific program, pre- and post-meeting documentation, and the workshop web page

(http://www.coaps.fsu.edu/RVSMDC/marine_workshop3/). The workshop focused on establishing collaboration between GOSUD and SAMOS and addressing the need of the research and operational community for high-quality underway oceanographic and meteorological observations from ships. The SAMOS initiative is working to improve access to calibrated, quality-controlled, surface marine meteorological data collected in-situ by automated instrumentation on research vessels (primarily) and merchant ships. GOSUD focuses on the collection, quality evaluation, and distribution of near surface ocean parameters (salinity and sea temperature) from vessels.

The workshop organizing committee (Shawn Smith, Robert Keeley, Thierry Delcroix, Mark Bourassa, and Christopher Fairall) brought together representatives from the scientific and operational marine observational communities. Participants from the U.S. government represented NOAA (ESRL, AOML, NDBC, NODC, OMAO), the Army Cold Regions Laboratory, and the U.S. Coast Guard. The U. S. university community was represented by the Woods Hole Oceanographic Institution, the Scripps Institution of Oceanography, the University of Miami, University of Alaska, Oregon State University, the National Center for Atmospheric Research, and the Florida State University. A significant international presence included representatives from the CSIRO (Australia); CNRS, IRD, IFREMER, and Mercator Ocean (France and New Caledonia); Environment Canada and MEDS (Canada); Tokai University and JAMSTEC (Japan); and the NOC (UK). Finally, the private sector was represented by Raytheon Polar Services, ADA Technologies, Earth and Space Research, and the International Sea Keepers Society.

The workshop was organized in three sessions: (1) parallel SAMOS and GOSUD technical working group meetings, (2) invited talks and posters focusing on applications of SAMOS and GOSUD observations and potential collaborations between marine observing programs, and (3) a plenary discussion encompassing sessions (1) and (2). A primary discussion topic was the scientific user needs for high-quality, automated, near-surface ocean and atmosphere measurements to achieve objectives ranging from satellite calibration and validation, ocean data assimilation, polar studies, air-sea flux estimation, and improving analyses of waves, precipitation, and radiation. The quantification and reduction of measurement bias and uncertainty was also addressed. The SAMOS and GOSUD working groups addressed both issues internal to each program as well as future interaction between SAMOS, GOSUD, and other international marine observing programs. The result of the workshop was a series of action items, recommendations, and reports (Smith 2006, Smith et al. 2006).

Additional collaborative activities are promoted by the SAMOS DAC. Colleagues at NOAA/ESRL/PSD and WHOI are working to develop a portable seagoing air-sea flux standard instrument suite. This system will be deployed on UNOLS and other research vessels to assess the accuracy of the SAMOS installations on those vessels. Once deployed recommendations for improving SAMOS on individual vessels can be made. The SAMOS DAC continues to promote the development of training materials for marine technicians and scientists planning to make meteorological measurements at sea. The first achievement of the training effort will be the Fall 2006 publication of a “Guide to making climate quality meteorological and flux measurements at sea”. Lead authors of the guide are Frank Bradley (CSIRO, Australia) and Chris Fairall (NOAA/ESRL/PSD) and the guide has been a collaborative effort of the SAMOS initiative and

the WCRP Working Group on Surface Fluxes. A new collaboration with the National Oceanography Centre (UK) and NOAA/ESRL will allow the SAMOS Initiative to undertake a program of computational fluid dynamics (CFD) modeling of research vessels. The primary focus of the CFD modeling is to identify the accelerations/decelerations of the wind flow over the vessel structure, allowing sensors to be moved to the "best" possible exposure on the vessel. The program will evaluate existing techniques and new methods to model the maximum number of vessels for the lowest cost. Finally, Smith has joined the Baseline Surface Radiation Network (BSRN) Ocean Working Group to expand the role of the SAMOS Initiative in resolving questions related to radiation measurements at sea.

SAMOS vs. bridge data comparisons [Deliverable 6]

A preliminary comparison was completed between marine meteorological observations that currently are available in the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) and those collected by automated science instrument systems on a dozen research vessels (R/Vs). Research vessels are typically equipped with both an automated science instrument system and a set of independent sensors used by the bridge crew for routine weather reports. The routine bridge reports are the typical source of observations in ICOADS and tend to be reported at one, three, or six hourly intervals. Hourly observations, derived from one-minute interval science system data, are used to evaluate the ICOADS reports from each R/V.

For this experiment, comparison data come from a dozen R/Vs that participated in the World Ocean Circulation Experiment. The comparison reveals large differences in temporal coverage provided by the bridge and science reporting systems on R/Vs. For the vessels examined, a large fraction of the bridge observations do not routinely appear in ICOADS (Figure 2). Using standard statistical techniques, differences in atmospheric pressure, sea and air temperature, humidity, and true wind direction and speed are examined. In some cases, large differences exist between bridge and science observations on individual vessels (Figure 3). Using available metadata (e.g., instrument heights, varying data sources in ICOADS, etc.) we will next consider possible causes for observed differences between the bridge and science observations and their impact on turbulent air-sea fluxes.

Publications and Reports

Refereed

Smith, S. R., 2006: Collaboration between Shipboard Oceanic and Atmospheric Programs. *EOS, Trans Amer. Geophys. Union*, **87**, 463, 466.

Gould, W. J and S. R. Smith, 2006: Research vessels: Underutilized assets for climate observations. *EOS, Trans Amer. Geophys. Union*, **87**, 214-215.

Technical reports

Rolph, J. J., and S. R. Smith, 2006: *Ron Brown IMET data quality control report: July 2005 – November 2005*. RVSMDC report 06-02, Center for Ocean-Atmospheric Prediction Studies, Florida State University, Tallahassee, Florida, 32306-2840, USA, 15 pp.

Smith, S. R., R. Keeley, and T. Delcroix, 2006: Report of the 1st Joint GOSUD/SAMOS Workshop. UCAR Joint Office for Science Support, Boulder, CO, USA, 63 pp. [Available from COAPS, The Florida State University, Tallahassee, FL 32306-2840].

Conference proceedings/presentations

Bourassa, M. A., 2006: Uncertainty in monthly surface wind fields from in situ observations. *1st Joint GOSUD/SAMOS Workshop*, 3-5 May 2006, Boulder, CO.

Bourassa, M. A., and P. J. Hughes, 2006: Hybrid surface turbulent fluxes model. *3rd SEAFLUX Workshop*, 3 March 2006, Tallahassee, FL.

Bourassa, M. A., 2005: New insights into how wind influences stress, and resulting implications to equivalent neutral winds and wind retrieval, *Ocean Vector Wind Science Team Meeting*, March, Seattle, WA.

Bourassa, M. A., 2005: On the important differences between earth-relative winds and equivalent neutral winds. *Scatterometer High Wind Model Function Meeting*, July, Pasadena, CA.

Bourassa, M. A., 2005: Wave Influences on Surface Turbulent Fluxes. *2nd International Workshop on Advances in the Use of Historical Marine Climate Data (MARCDAT-II)*, 17-20 October 2005, Exeter, U.K, 14.

Smith, S. R., 2006: Progress of the Shipboard Automated Meteorological and Oceanographic System (SAMOS) initiative. *Short Abstract*, *Climate Observation Program 4th Annual System Review*, Silver Spring, MD, USA, NOAA (in press).

Smith, S. R., 2006: A Comparison of SAMOS and Bridge Observations on Research Vessels, *1st Joint GOSUD/SAMOS Workshop*, 3-5 May 2006, Boulder, CO.

Smith, S. F., 2006: High quality R/V observations for air-sea flux analysis. *3rd SEAFLUX Workshop*, 3 March 2006, Tallahassee, FL.

Smith, S. R., S. D. Woodruff, and S. Worley, 2005: Marine climatology from research vessels. Abstracts from *2nd International Workshop on Advances in the Use of Historical Marine Climate Data (MARCDAT-II)*, 17-20 October 2005, Exeter, UK, 43.

Smith, S. R., 2005: Progress of the shipboard automated meteorological and oceanographic system (SAMOS) initiative. Abstracts from *2nd International Workshop on Advances in the Use of Historical Marine Climate Data (MARCDAT-II)*, 17-20 October 2005, Exeter, UK, 48.

Smith, S. R., 2005: Show and tell: Shipboard Automated Meteorological and Oceanographic System (SAMOS). *UNOLS Research Vessel Technical Enhancement Committee (RVTEC) Annual Meeting*, 8-10 November 2005, Corvalis, OR.

Figures

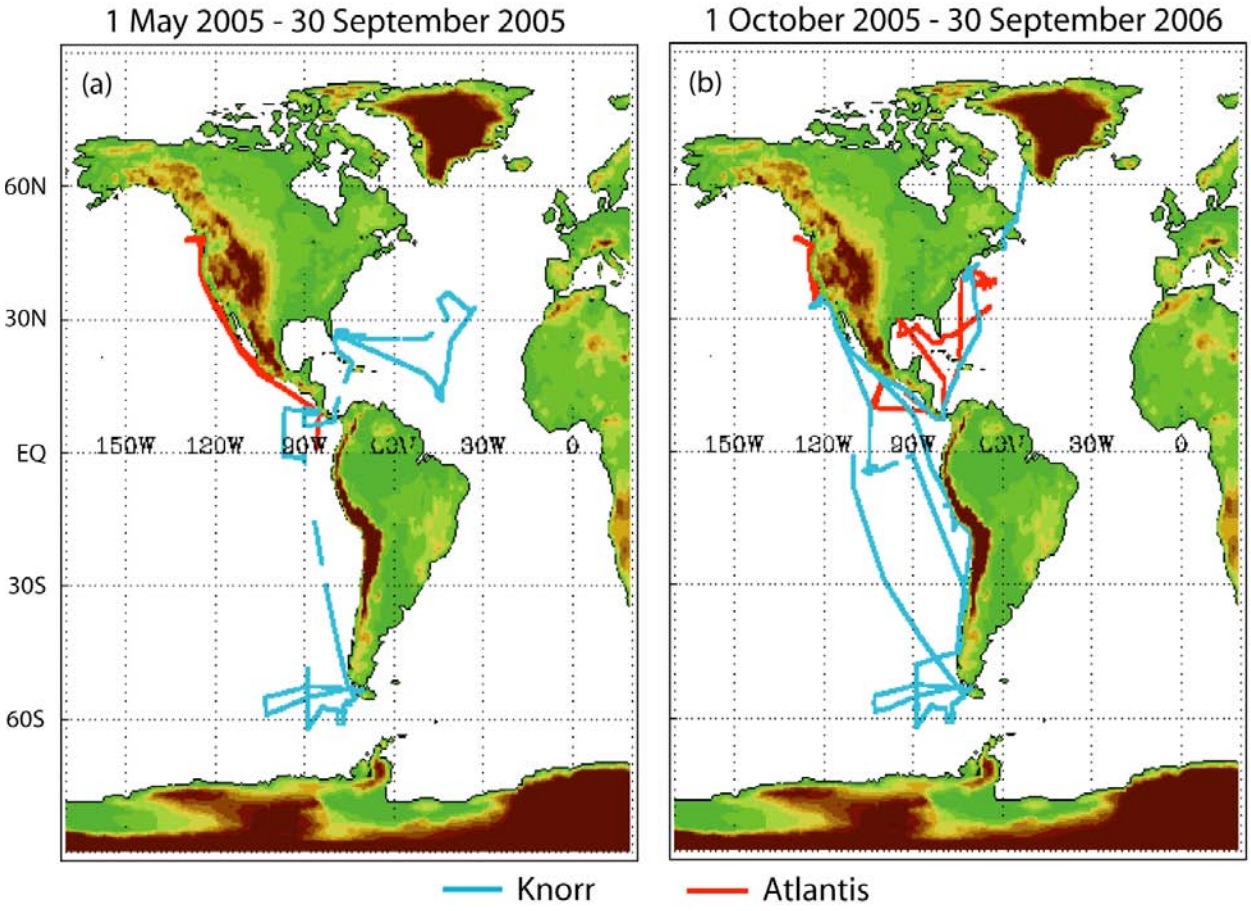

Figure 1. Cruise tracks for the *Knorr* and *Atlantis* for which SAMOS data were received, processed, and distributed by the DAC. The period of record is (a) 1 May 2005 through 30 September 2005 and (b) 1 October 2005 through 30 September 2006.

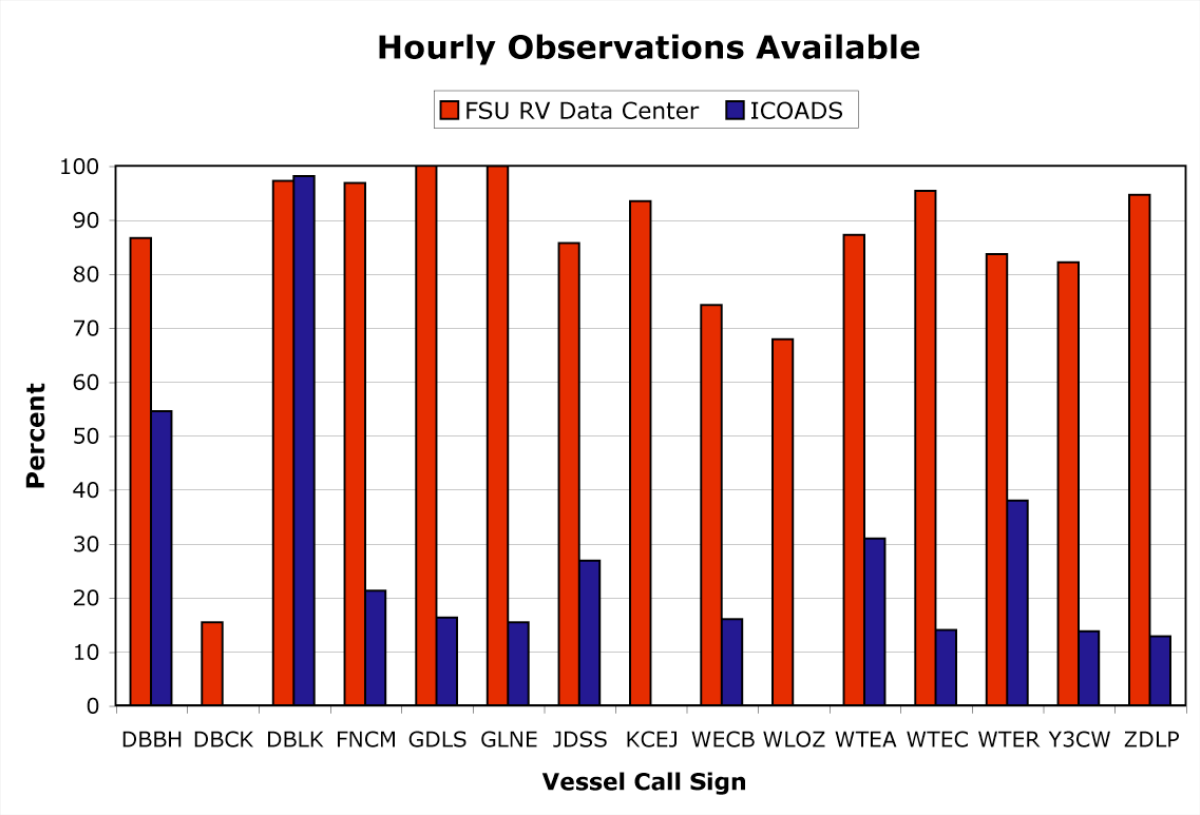

Figure 2: Percentage of hourly marine reports available during 90 WOCE cruises from the ICOADS (bridge) and FSU R/V data center. Vessels evaluated include the *Meteor* (DBBH), *Heincke* (DBCK), *Polarstern* (DBLK), *L'Atalante* (FNCM), *Charles Darwin* (GDLS), *Discovery* (GLNE), *Hakuho Maru* (JDSS), *Knorr* (KCEJ), *Melville* (WECB), *Maurice Ewing* (WLOZ), *Discoverer* (WTEA), *Ronald Brown* (WTEC), *Malcolm Baldrige* (WTER), *A. von Humboldt* (Y3CW); and the *James C. Ross* (ZDLP).

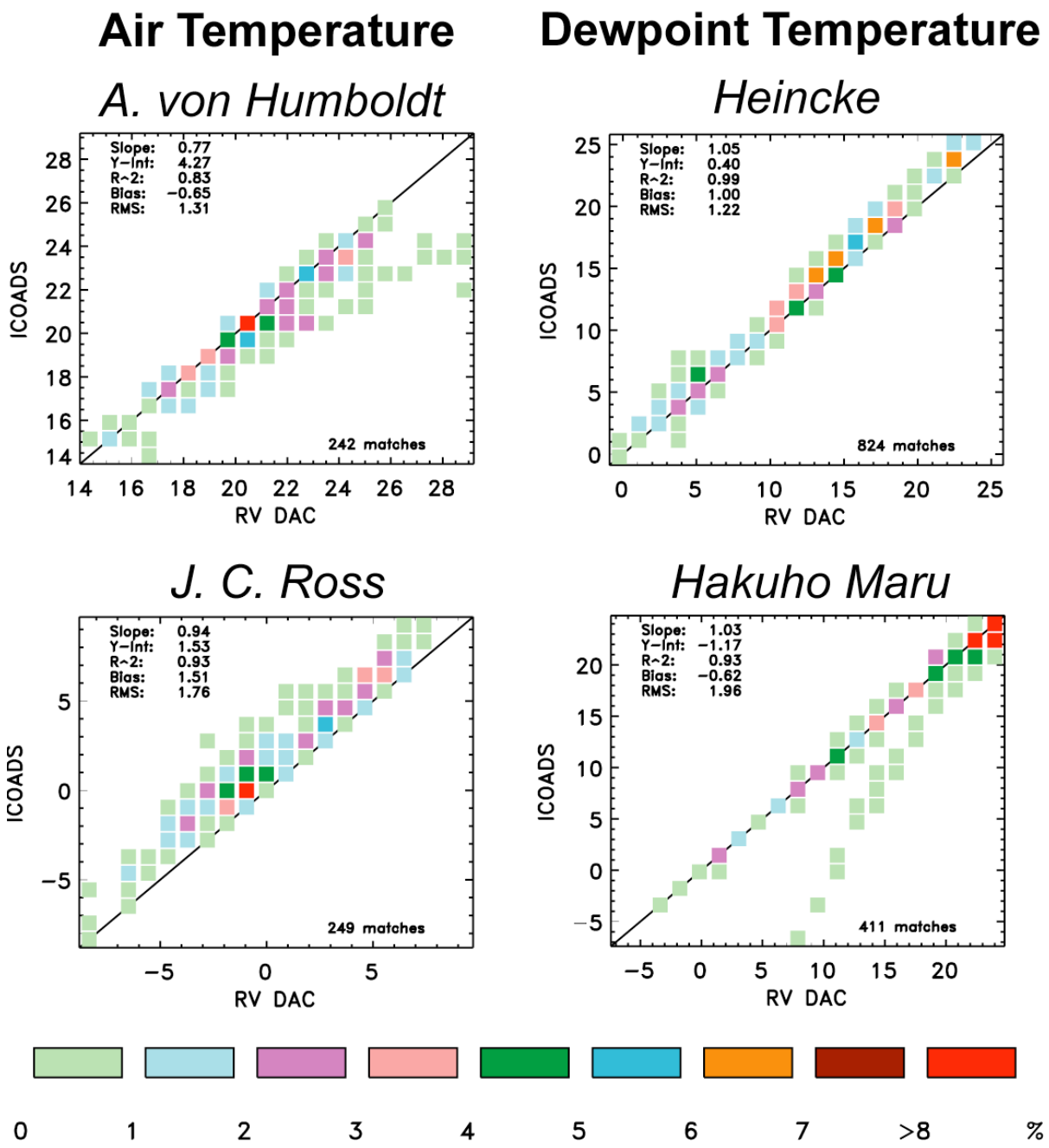

Figure 3: Comparison histograms for unadjusted air (left) and dewpoint (right) temperature (˚C). Histograms represent the percentage of one-to-one matches that fall within each bin on the graph (similar to a scatter plot). Each graph is divided into 20 equal bins on the x and y axis. Percentages are calculated relative to the number of matches for each variable (lower right on each plot). Plots are labeled with the vessel that provided the observations.